

Low-Profile Planar Inverted-F Antenna for Ultrawideband Applications

Junsik Yun^{1,2} · Jaehoon Choi^{1,*}

Abstract

In this paper, a low-profile planar inverted-F antenna (PIFA) for ultrawideband (UWB) applications is proposed. The antenna consists of a PIFA and a ground plane with a slot. The addition of the slot not only improves the impedance matching of the PIFA but also forms an additional resonance. Therefore, the proposed antenna has a wideband characteristic covering the full UWB frequency range (3.1 GHz to 10.6 GHz) and a stable and nearly omnidirectional radiation pattern. The antenna also has a smaller volume and thickness compared to previous UWB PIFAs.

Key Words: Low-Profile Antenna, PIFA, Slot, UWB.

I. INTRODUCTION

Recently, ultrawideband (UWB) communication systems have received increasing attention for automotive, medical, and radar applications because they support a high data rate, low power consumption, and are low cost [1–5]. Because UWB communication systems are integrated into a variety of electronic devices, the available area for a universal UWB antenna is limited [6]. The UWB antenna should not only have a compact size, a low profile, and a low cost, but should also have a stable and omnidirectional radiation pattern [7–9]. Also, the Federal Communications Commission (FCC) requires that UWB antennas operate in the frequency range from 3.1 GHz to 10.6 GHz [10].

The planar inverted-F antenna (PIFA) with a resonant length of $\lambda/4$ has a compact size, a low profile, is lightweight, and is also easy to fabricate, which makes the PIFA a good can-

didate for radio communication applications [11, 12]. However, because the PIFA features a narrow bandwidth, it is not suitable for UWB applications [13]. In order to satisfy the required performance over the UWB frequency range, the PIFAs with bandwidth enhancement technologies have been studied [13–16]. Typical bandwidth-enhanced PIFAs include an inverted-L-shaped parasitic element and a rectangular parasitic element [13], double posts [14], a dual-PIFA [15], and a parasitic planar inverted-L element [16]. However, these antennas are not suitable for UWB applications due to their large height and size.

To overcome this problem, a low-profile PIFA with a slotted ground plane for UWB applications is proposed. This antenna has a bandwidth covering the full UWB frequency range (3.1 GHz to 10.6 GHz), with improved impedance matching by utilizing the additional resonance of the slot on the ground plane. The antenna has a stable and nearly omnidirectional ra-

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diation pattern over the full UWB frequency range.

II. ANTENNA DESIGN

Fig. 1 shows the geometry of the proposed antenna. The proposed antenna consists of a PIFA element and a ground plane with a slot. The PIFA is placed on the top of an FR4 substrate ($\epsilon_r = 4.4$) with 1-mm thickness. Wideband impedance matching of the PIFA is realized by adding a slot in the ground plane [17]. The ground plane is located on the bottom of the substrate and has a total size of $30 \text{ mm} \times 50 \text{ mm}$. The parameters of the antenna are: $L_1 = 12.5 \text{ mm}$, $L_2 = 5 \text{ mm}$, $L_3 = 8.5 \text{ mm}$, and $W = 4 \text{ mm}$.

To investigate the effect of the slot, reflection coefficients of the proposed antenna and the reference antenna are compared in Fig. 2. The reference antenna has a basic PIFA structure that is the same as the proposed antenna, except without a slot. By adding the slot in the ground plane, the impedance matching of the PIFA is improved and the additional resonance f_2 is generated, which makes the -10 dB reflection coefficient bandwidth cover the full UWB frequency range. The fundamental resonance of the PIFA element is f_1 , and f_3 , f_4 , and f_5 are harmonic resonances.

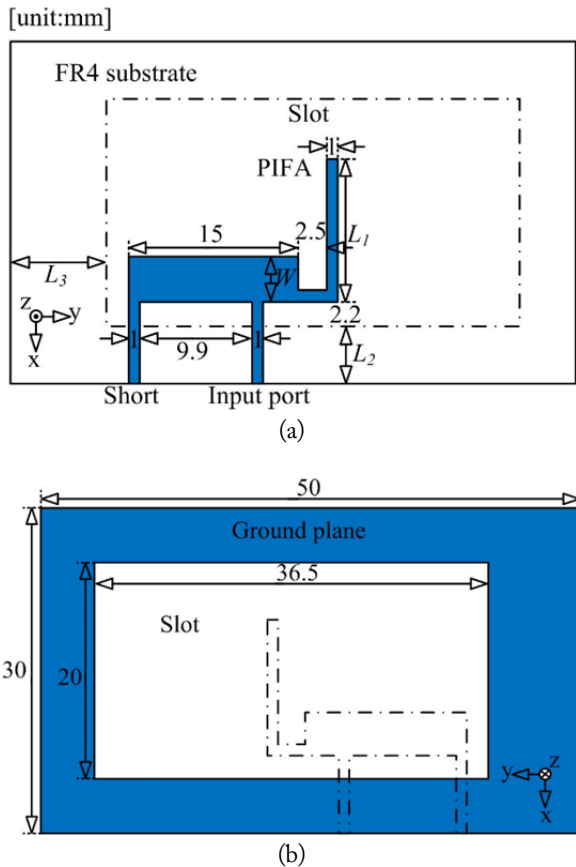


Fig. 1. Geometry of the proposed antenna: (a) top view, (b) bottom view.

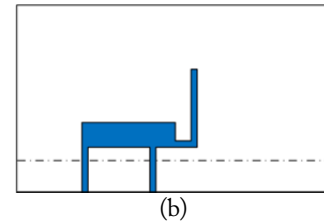
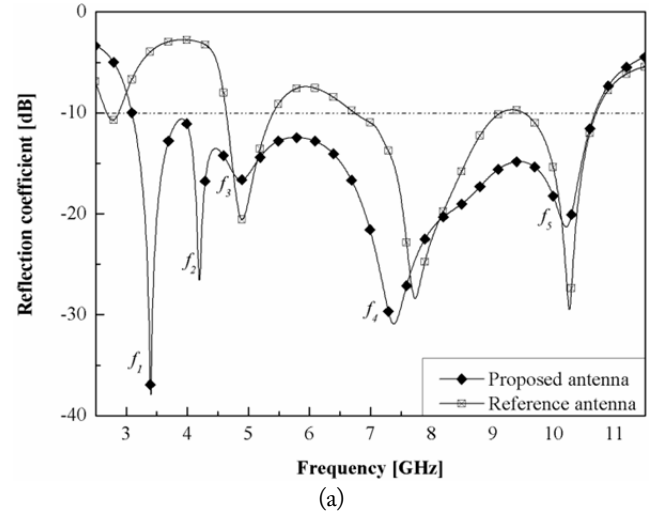


Fig. 2. Simulated reflection coefficients of the proposed antenna (a) and the reference antenna (b).

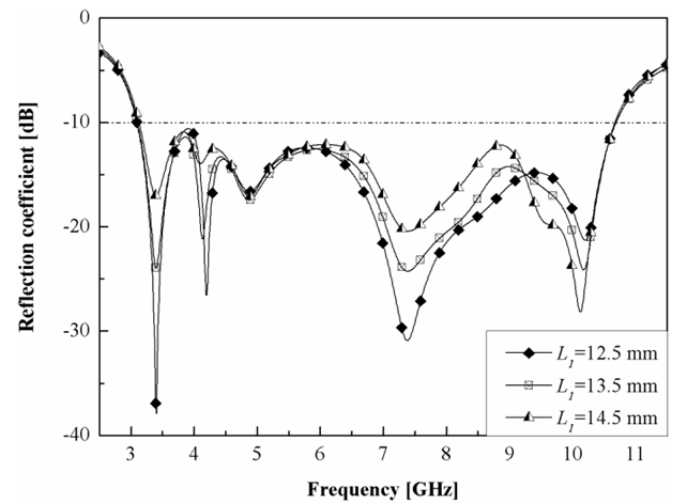
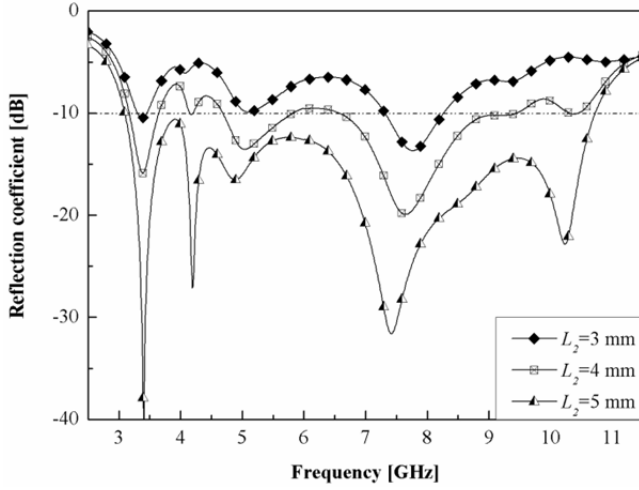
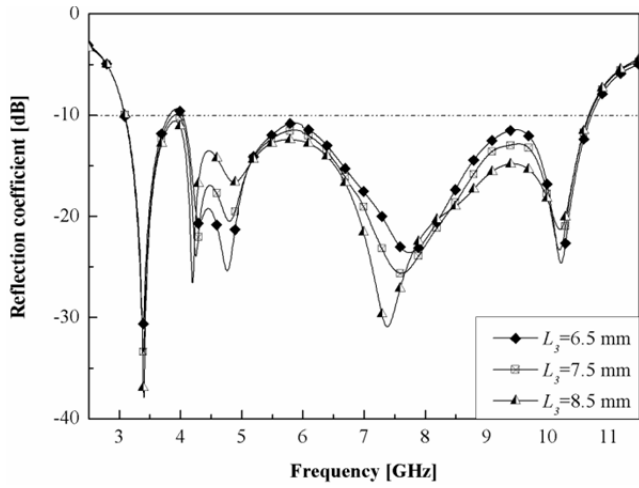


Fig. 3. Simulated reflection coefficients for various values of length L_1 .

III. SIMULATED RESULTS AND ANALYSIS

Fig. 3 illustrates simulated reflection coefficients for various values of L_1 . As L_1 decreases, the impedance matching at f_1 , f_2 , and f_4 is improved. The optimum performance is established when L_1 is 12.5 mm . The simulation results are analyzed using HFSS (High Frequency Structure Simulator; ANSYS Inc., Canonsburg, PA, USA).

In Fig. 4, simulated reflection coefficients for various values of L_2 are shown. As L_2 increases, the bandwidth of the antenna

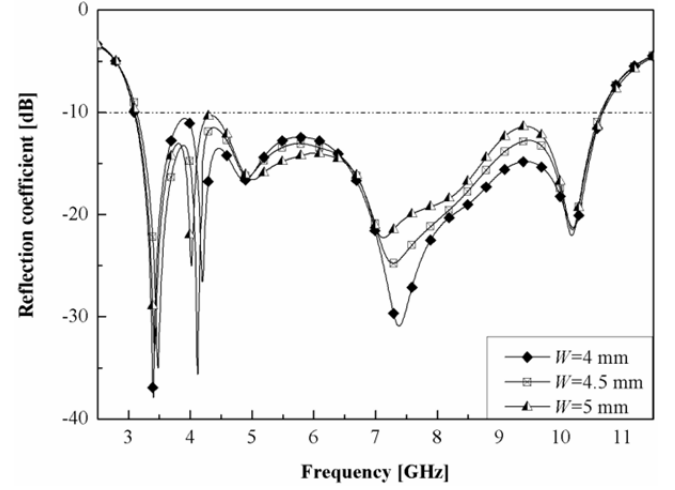
Fig. 4. Simulated reflection coefficients for various values of length L_2 .Fig. 5. Simulated reflection coefficients for various values of length L_3 .

broadens. Increasing L_2 both reduces the gap distance and affects the coupling between the PIFA and the ground plane, which in turn improves the impedance matching of the antenna. In order to cover the full UWB frequency range, L_2 is set to 5 mm.

Fig. 5 shows simulated reflection coefficients for various values of L_3 . As L_3 increases, the coupling between the PIFA and the ground plane changes, and the impedance matching between both f_1 and f_2 and f_3 and f_5 is improved. The full UWB frequency range is covered when $L_3 = 8.5$ mm.

In Fig. 6, simulated reflection coefficients for various values of W are illustrated. As W decreases, the impedance matching of f_4 , as well as between f_4 and f_5 , is improved. The reflection coefficient of the antenna is optimized to satisfy the full UWB frequency range when W is 4 mm.

Fig. 7 illustrates the simulated surface current distributions of the proposed antenna, illustrating the coupling between the PIFA and the ground plane. The current distributions in Fig. 7(a), (c), (d), and (e) show that the PIFA has an effective electrical length of $\lambda/4$, $\lambda/2$, $3\lambda/4$, and λ at 3.4 GHz, 4.88 GHz,

Fig. 6. Simulated reflection coefficients for various values of width W .

7.39 GHz, and 10.2 GHz, respectively. The slot operates as a resonator because of the coupling between the PIFA and the ground plane, as shown in Fig. 7(b).

IV. MEASURED RESULTS

A prototype of the proposed antenna is shown in Fig. 8, and simulated and measured reflection coefficients are compared in Fig. 9. The measured result is virtually identical to the simulated result. The measured -10 dB reflection coefficient bandwidth (3 GHz to 10.65 GHz) covers the full UWB frequency range.

Fig. 10 shows simulated and measured radiation patterns of the proposed antenna. The measured results agree with the simulated results and show a stable and nearly omnidirectional radiation pattern. The measured peak gains of the antenna are 4.94 dBi at 3.4 GHz, 3.8 dBi at 4.19 GHz, 3.31 dBi at 4.88 GHz, 2.78 dBi at 7.39 GHz, and 5.38 dBi at 10.2 GHz.

Volume, thickness, and bandwidth comparisons between previous UWB PIFAs and the proposed antenna are given in Table 1. Previous UWB PIFAs also are either not satisfying the full UWB frequency range despite their larger volume [13–15]

Table 1. Volume, thickness, and bandwidth comparisons between previous UWB PIFAs and the proposed antenna

Previous works	Volume occupation (mm ³)	Thickness (mm)	-10 dB reflection coefficient bandwidth (GHz)
[13]	26,400	11	3.4–10.7
[14]	1,705	5.53	3.168–4.860
[15]	19,200	6	3.1–4.8
[16]	3,037	7.5	3–11
Proposed antenna	1,500	1	3–10.65

UWB=ultrawideband, PIFA=planar inverted-F antenna.

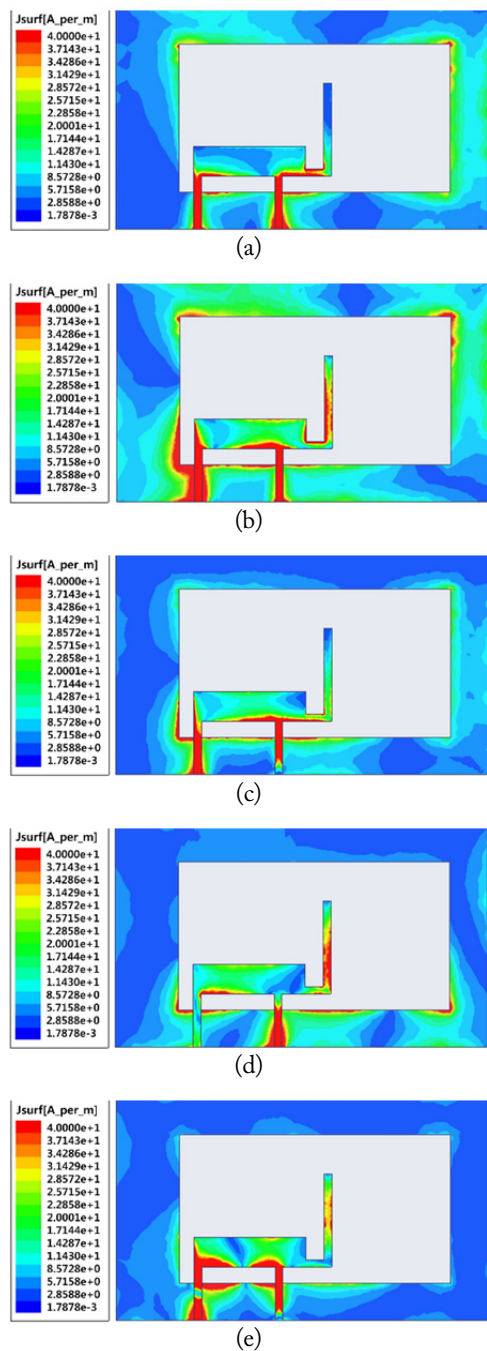


Fig. 7. Simulated surface current distributions of the proposed antenna: (a) 3.4 GHz, (b) 4.19 GHz, (c) 4.88 GHz, (d) 7.39 GHz, and (e) 10.2 GHz.

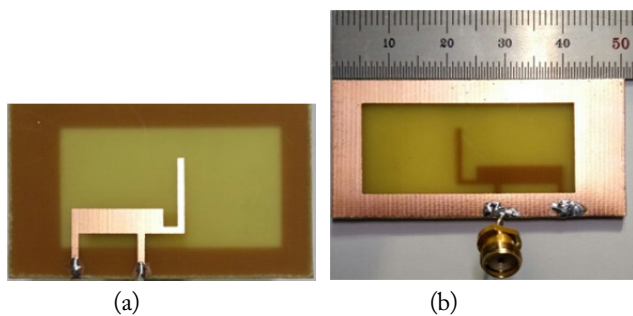


Fig. 8. Fabricated antenna: (a) top view, (b) bottom view.

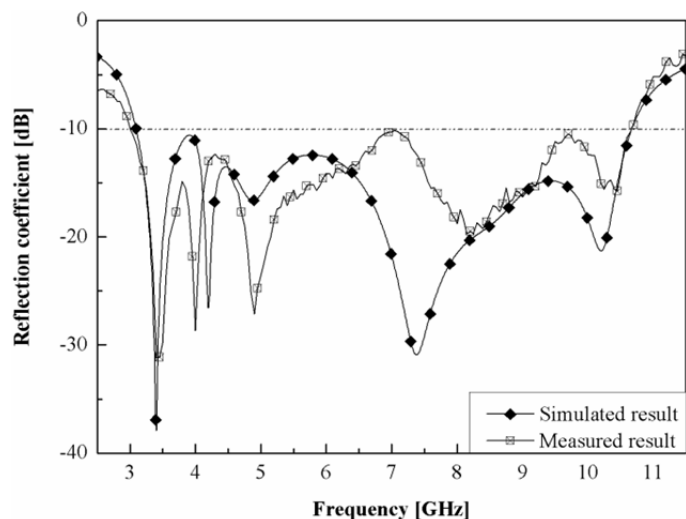


Fig. 9. Simulated and measured reflection coefficients of the proposed antenna.

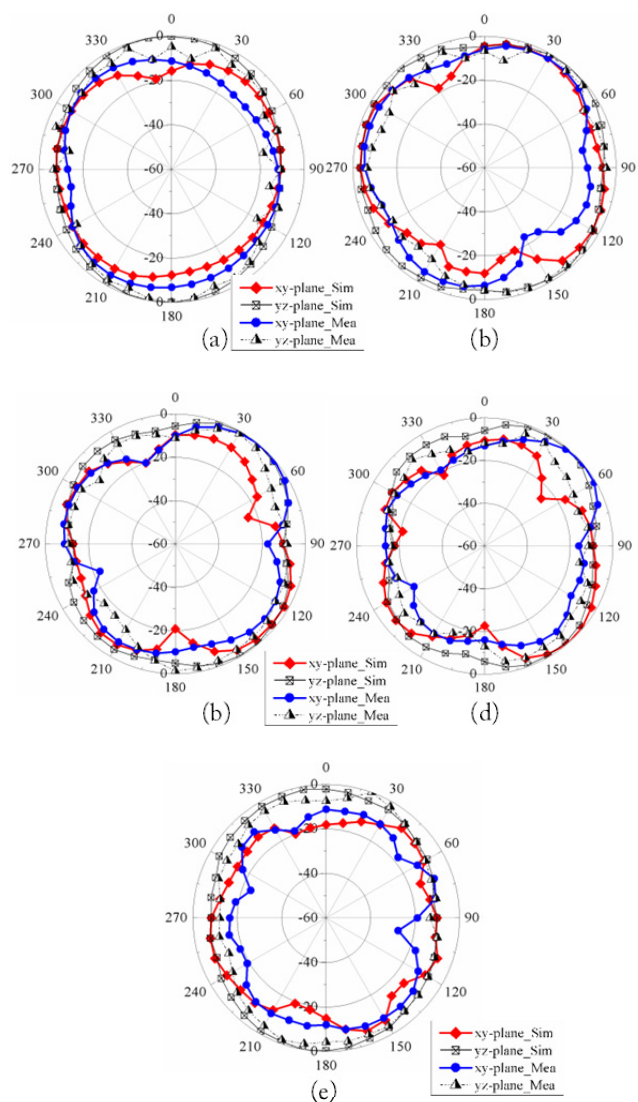


Fig. 10. Simulated and measured radiation patterns of the proposed antenna: (a) 3.4 GHz, (b) 4.19 GHz, (c) 4.88 GHz, (d) 7.39 GHz, and (e) 10.2 GHz.

or satisfying the full UWB frequency range with larger volume [16]. As shown in Table 1, the proposed antenna has the smallest volume and thickness. The overall volume and thickness of the proposed antenna is minimized because wideband impedance matching is obtained by electromagnetic coupling between the PIFA and the thin ground plane.

V. CONCLUSION

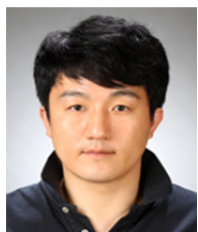
A low-profile PIFA with a slot for UWB applications is proposed in this paper. The addition of a slot on the ground plane improves the impedance matching of the PIFA and adds an additional resonance due to coupling between the PIFA and the ground plane. Consequently, the antenna has a wide -10 dB reflection coefficient bandwidth of 7.65 GHz covering the full UWB frequency range (3.1 GHz to 10.6 GHz). The antenna also provides a stable and nearly omnidirectional radiation pattern over the full UWB frequency range. These advantages make the proposed antenna a promising candidate for UWB applications.

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